# Canadian Clean Power Coalition: Current Status of Clean Coal Technologies

**Presented to**

## Wisconsin Clean Coal Study Group
## Madison, WI

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CANADIAN CLEAN POWER COALITION


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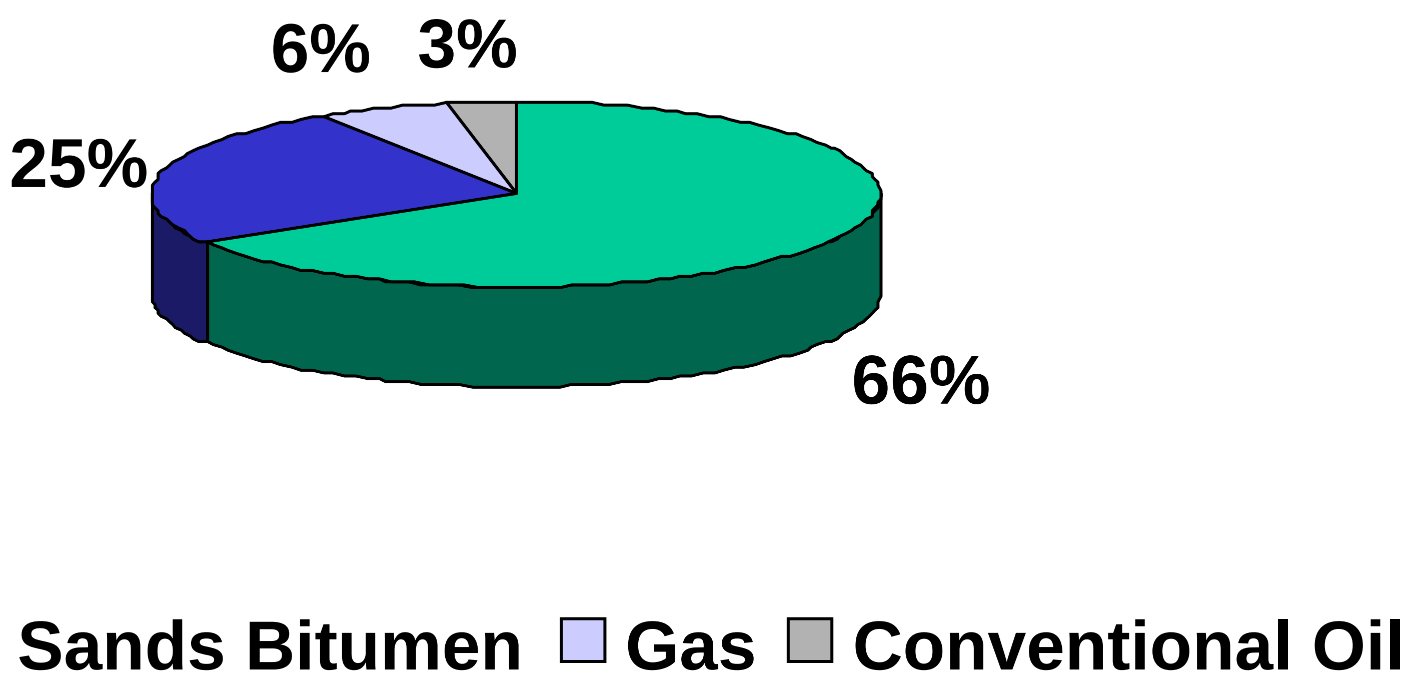
# Presentation Outline

- Canadian Clean Power Coalition Overview
  - Phase I Studies
    - Phase II Status
      - Gasification Technologies
      - ASC Technologies

# Canada's Fossil Fuel Energy Reserves



# The Canadian Clean Power Coalition

- Formed in 2000
- A national association of Canadian coal and coal-fired electricity producers
- Represents over 90 percent of Canada's coal-fired electricity generation
- Industry/government partnership
- Objective is to demonstrate that coal-fired electricity generation can effectively address all environmental issues projected in the future, **including $CO_2$**

*www.canadiancleanpowercoalition.com*

# Current Coalition Participants

- ATCO Power Canada Ltd.
- Basin Electric Power Cooperative (North Dakota)
- EPCOR Utilities Inc.
- EPRI (Electric Power Research Institute)
- Luscar Ltd.
- Nova Scotia Power Inc.
- Saskatchewan Power Corporation
- TransAlta Corporation

In addition, in Phase I, IEA (GHG and CCC) and Ontario Power Generation Inc. participated

# Government Participation

- Natural Resources Canada
- Alberta Energy Research Institute
- Saskatchewan Industry and Resources

# CCPC Goal: Build and Operate a Clean Coal Demonstration Plant

- Construct and operate a full-scale demonstration project to remove greenhouse gas and all other emissions of concern from a coal-fired power plant by 2012
- Provide flexible fuel capability– bituminous, sub-bituminous, lignite, and petroleum coke
- To accomplish this at a competitive cost of power

# CCPC Plan

- 2000: Formation & planning
- 2001 - 2003: Phase I technology studies
- 2004: Results assessment and Phase II formation
- 2004 - 2006: Phase II optimization studies

2006: Status assessment & commitment to demo project

2007 - 2011: Design & construction

2012: Operation

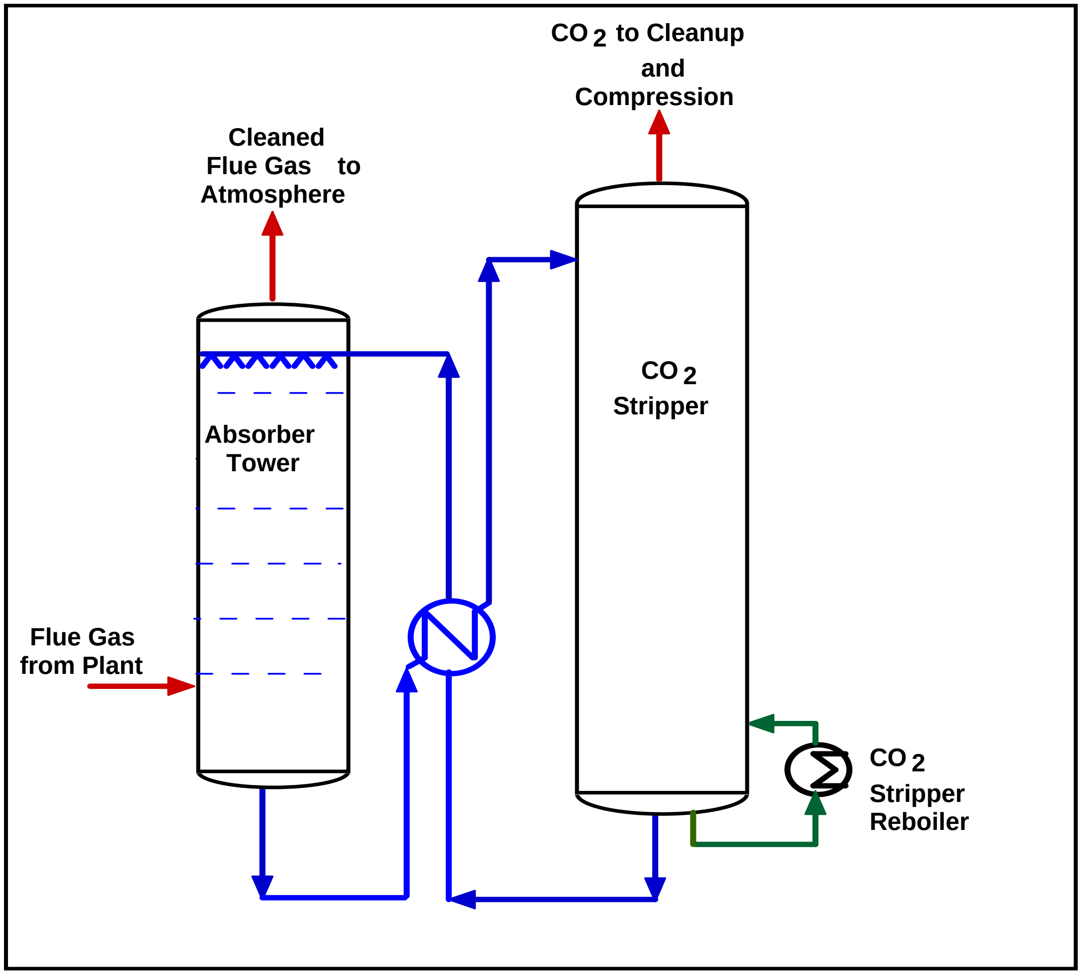
# Phase I Studies 2001 - 2003

- Review of clean coal technology pre-selected Integrated Gasification Combined Cycle (IGCC) as the likely best option.
- Emission control technology evaluation looked at the limits of "how low can we go" to set the goals for the plant design studies.
- Three major plant design concepts were studied:
  - Conventional steam cycles with amine scrubbing for $CO_2$ control
  - Conventional steam cycles using $CO_2$/Oxygen combustion for $CO_2$ control
  - IGCC with CO shift and $CO_2$ extraction
  - Both new plant and retrofit cases examined.
- Review of options for use or storage of the extracted $CO_2$

# Retrofit Options for $CO_2$ Extraction

- Options evaluated:
  - Amine scrubbing of flue gas
  - $CO_2/O_2$ Combustion
- Major challenges to reduce auxiliary energy requirements
- Focus on integration options

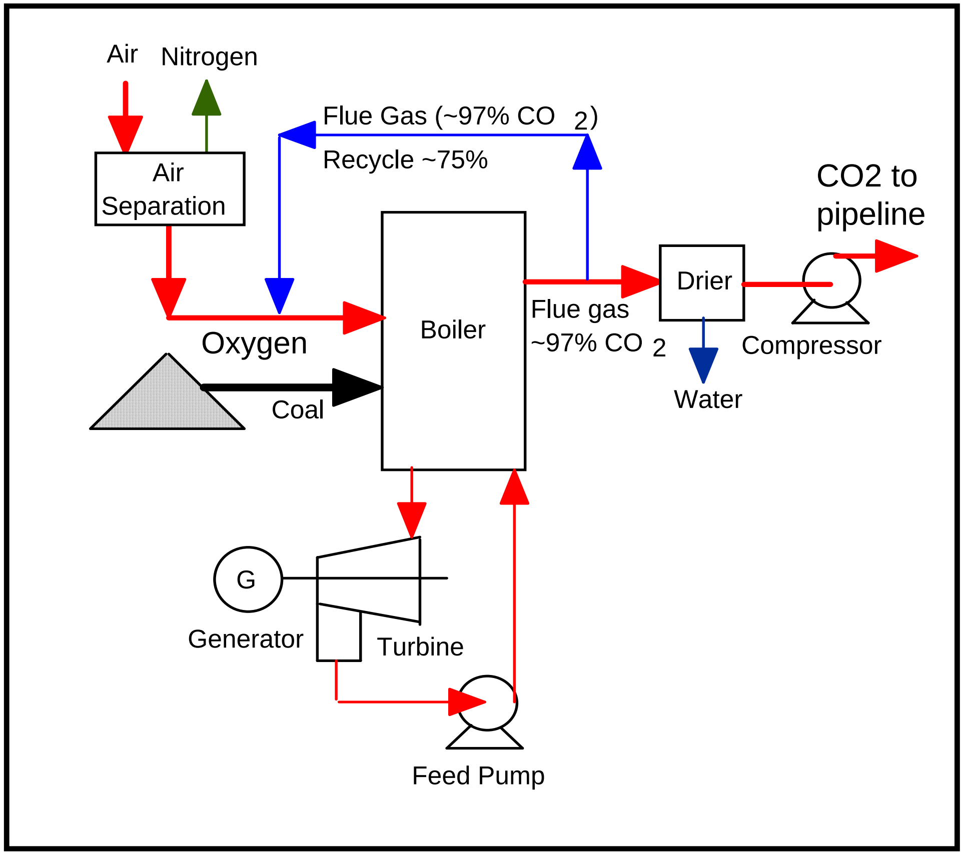
# Flue Gas Amine Scrubbing




## Issues

- High amine regeneration heat load
- Fate of mercury in amine system

# $CO_2/O_2$ Combustion



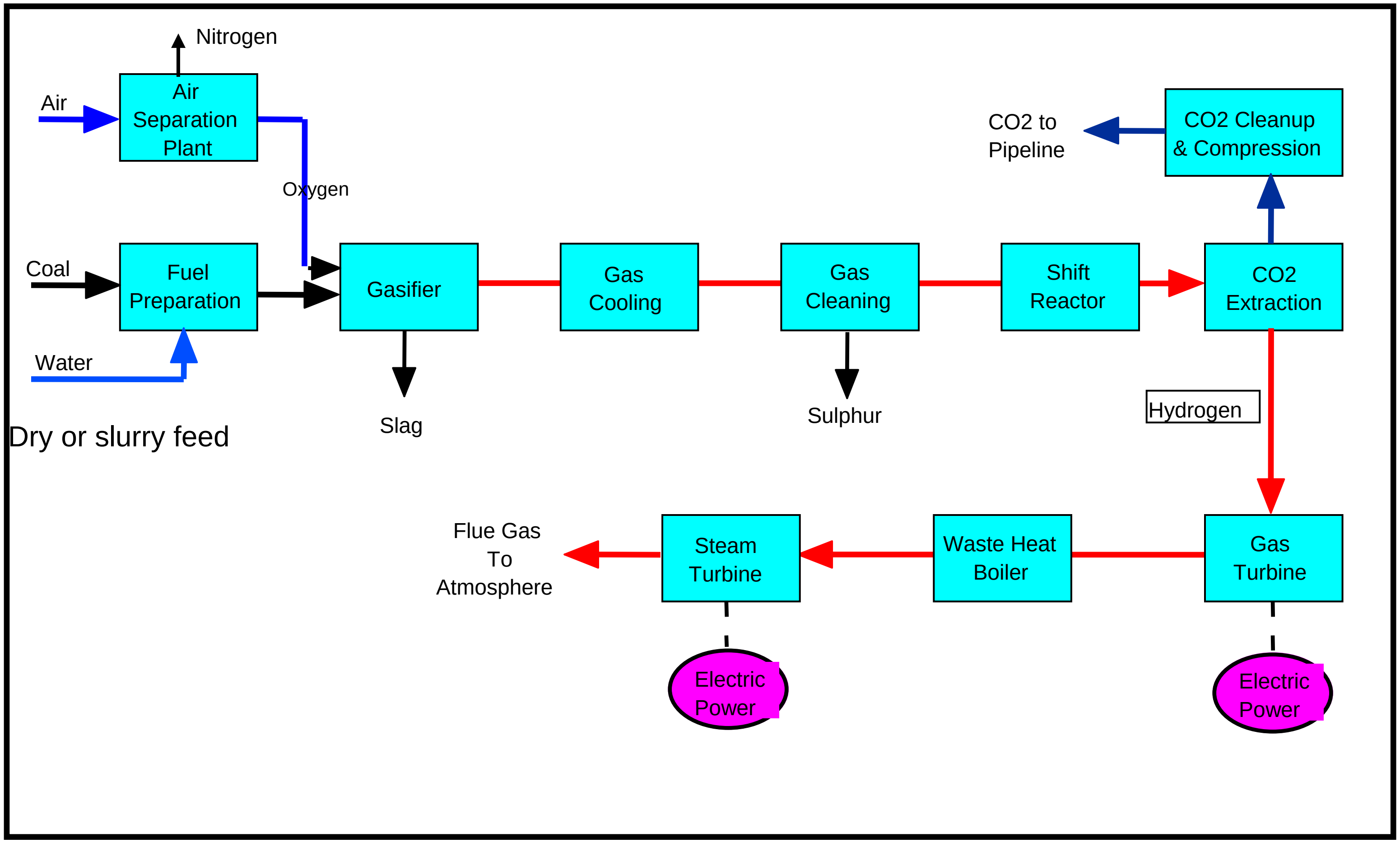

## <u>Issues</u>

- Boiler performance with recycle flue gas
- Air entrainment
- Shaft power for ASU
- Quality of $CO_2$

# Greenfield Plant Technology Options

- Pre-screening study showed gasification likely to be the best option
- Provides high efficiency, ease of emission reduction and lowest energy penalty to add $CO_2$ capture
- Efficiency improvements from new advanced gas turbines

# Coal Gasification- IGCC with $CO_2$ Capture



# IGCC Issues

- Gasification characteristics of bituminous, sub-bituminous and lignite coals
- Gasifier feed systems: wet vs dry vs $CO_2$ slurry
- Syngas composition, clean-up, fate of mercury
- Purity specifications of captured $CO_2$
- Reliability of gasification plant to meet power generation service factors
- Integration of plant components to minimize capital costs and optimum performance

# Emissions Control Study

- Looked at retrofit emission control for NOx, SOx, Hg, particulates and all other pollutants
- Excluded $CO_2$
- Allows net costs for $CO_2$ to be calculated by comparison with the other studies

# $CO_2$ Utilization & Storage Evaluation

- Reviewed prior work on EOR & ECBM use in western sedimentary basin
- Separate study for Nova Scotia to examine potential for ECBM in coal beds
- Evaluation of storage options in deep saline aquifers and depleted reservoirs

# Phase I Dates

- Pre-screening study completed early 2002
- Control options for emissions all except $CO_2$ completed December 2002
- Studies to assess technology options and costs for retrofit plant options and greenfield plant options completed July 2003
- Examination of $CO_2$ utilization and storage completed August 2003 (Nova Scotia portion  completed early 2004)
- Phase I final report completed early 2004.

# Plants selected for comparative evaluation

- Trenton # 6, a 150 MWe bituminous coal fired power plant located in Nova Scotia
- Shand, a 300 MWe lignite coal fired power plant located in Saskatchewan
- Genesee, a 400 MWe sub-bituminous coal fired power plant located in Alberta

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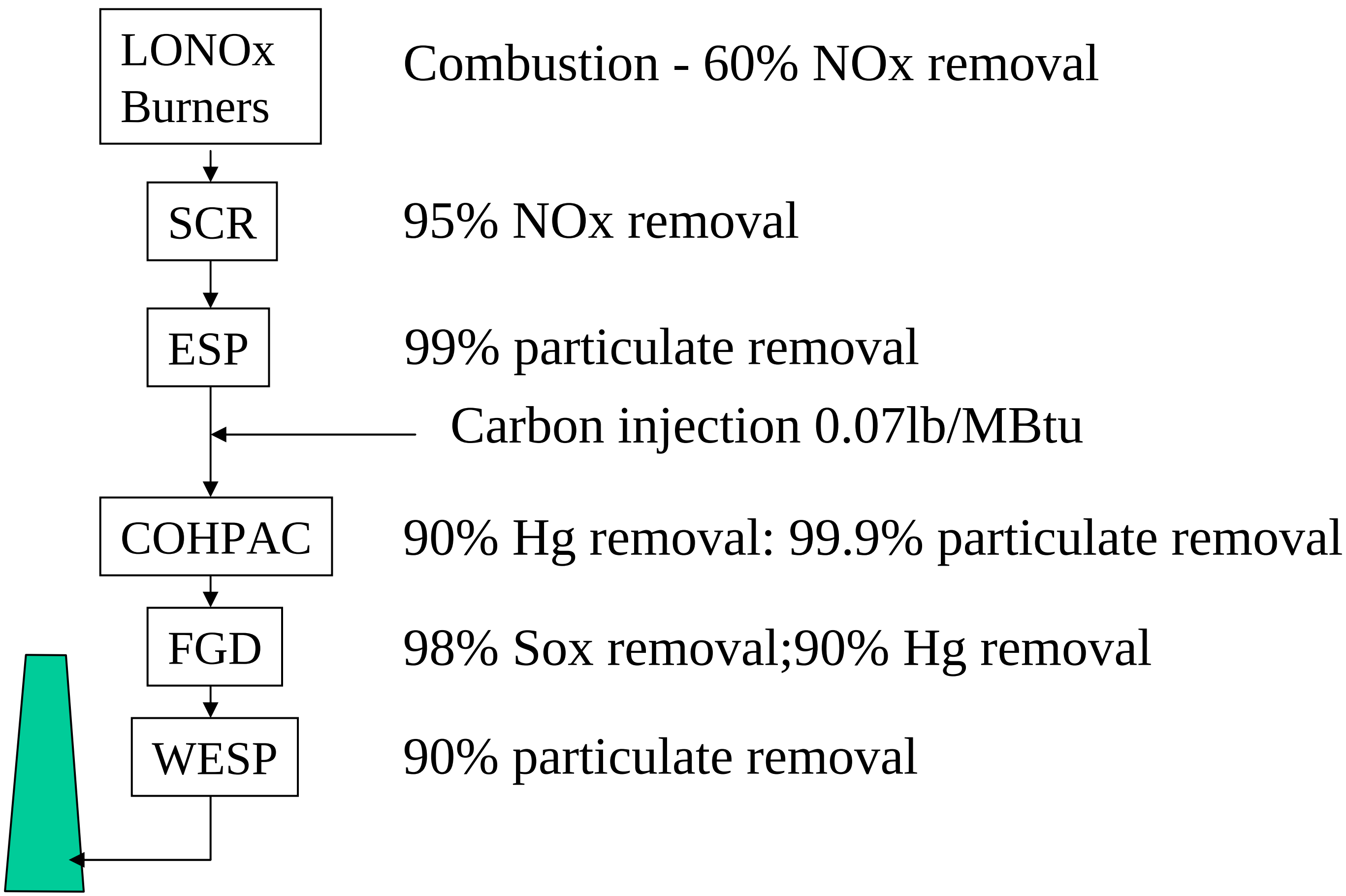
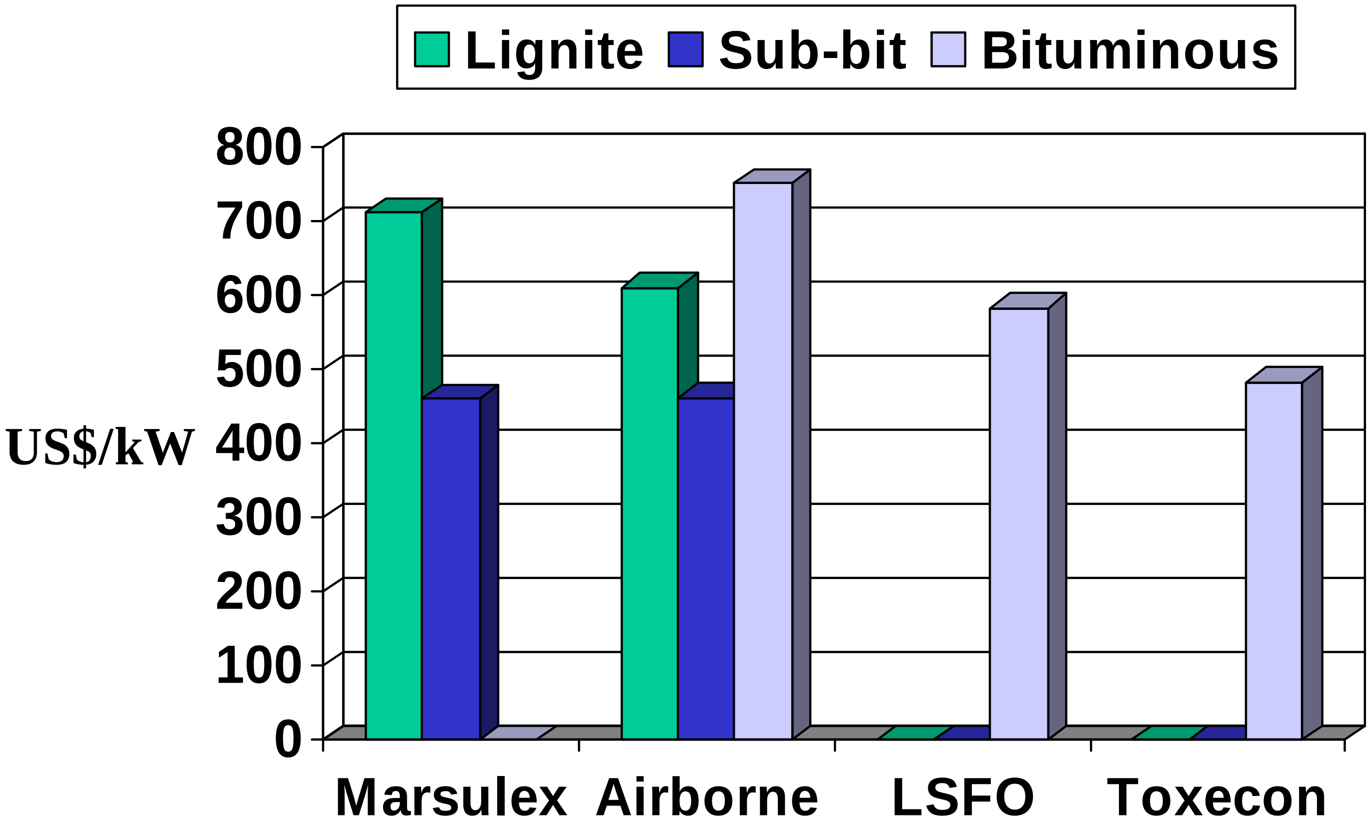
# Target Emission Levels-Comparison with Natural Gas Combined Cycle (NGCC)

| **Type** | Units | Lignite | Sub-bit | Bitumi-nous | NGCC |
|---|---|---|---|---|---|
| **NOx** | Gram/MWh net | 27.6 | 27.6 | 27.6 | 27.6 |
| **SOx** | Ng/Joules fired | 0.7 | 0.7 | 0.7 | 0.7 |
| **$PM_{10, 2.5}$** | Ng/Joule fired | 2 | 2 | 2 | 2 |
| **Mercury** | Pg/J | 0.5 | 0.3 | 0.3 | N/A |
| **CO** | ppm @ 3% O2 | 40 | 40 | 40 | 45 |
| **SO3** | ppmv | 5 | 5 | 5 | N/A |
| **NH3** | ppmv | 1 | 1 | 1 | 1 |
| **Heavy Metals**<br>**Se**<br>**As**<br>**Cd** | $Mg/Nm^3$ | <br>6<br>6<br>2 | <br>6<br>6<br>2 | <br>6<br>6<br>2 | |

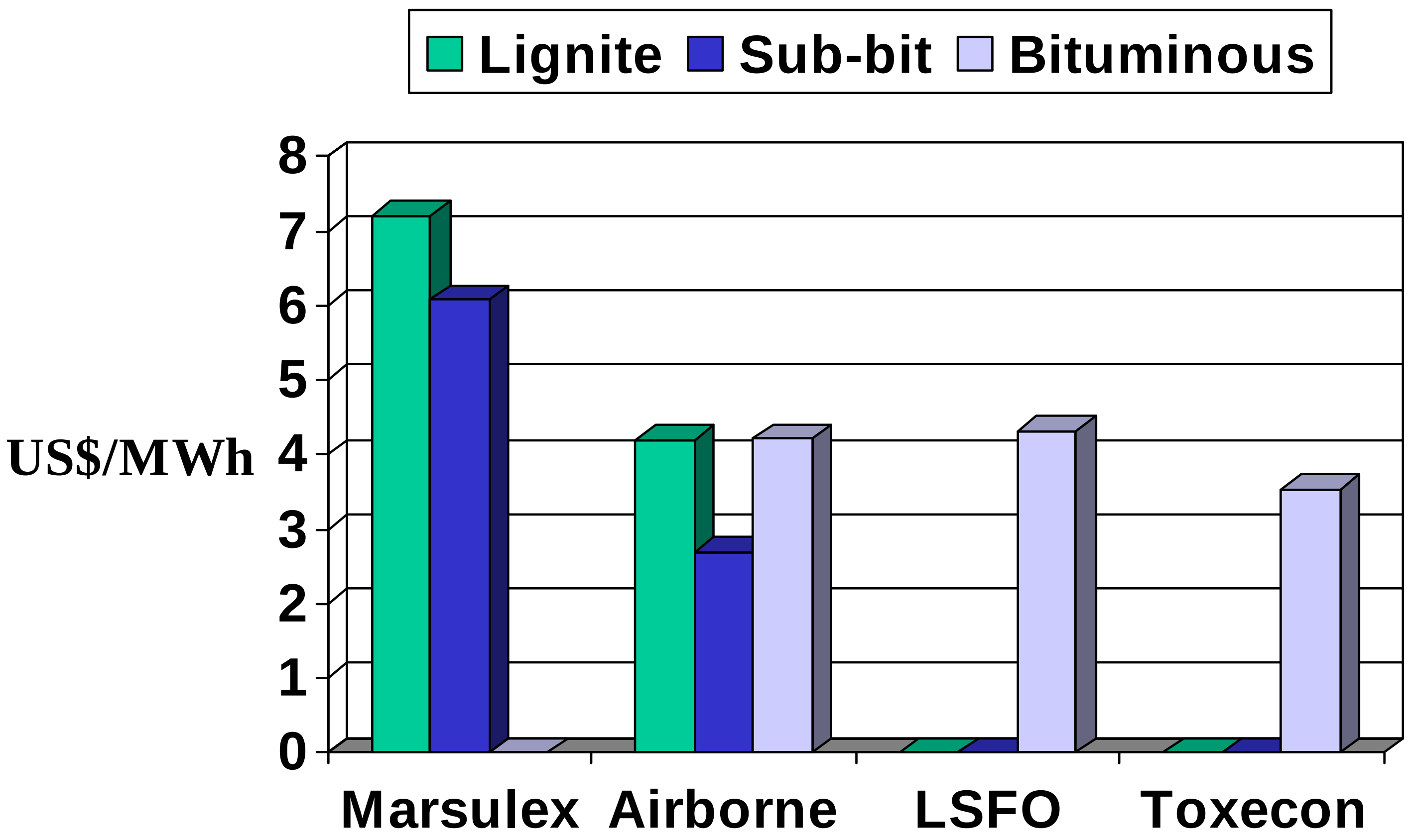
# Evaluation of Retrofit Plants for all Emissions Except $CO_2$



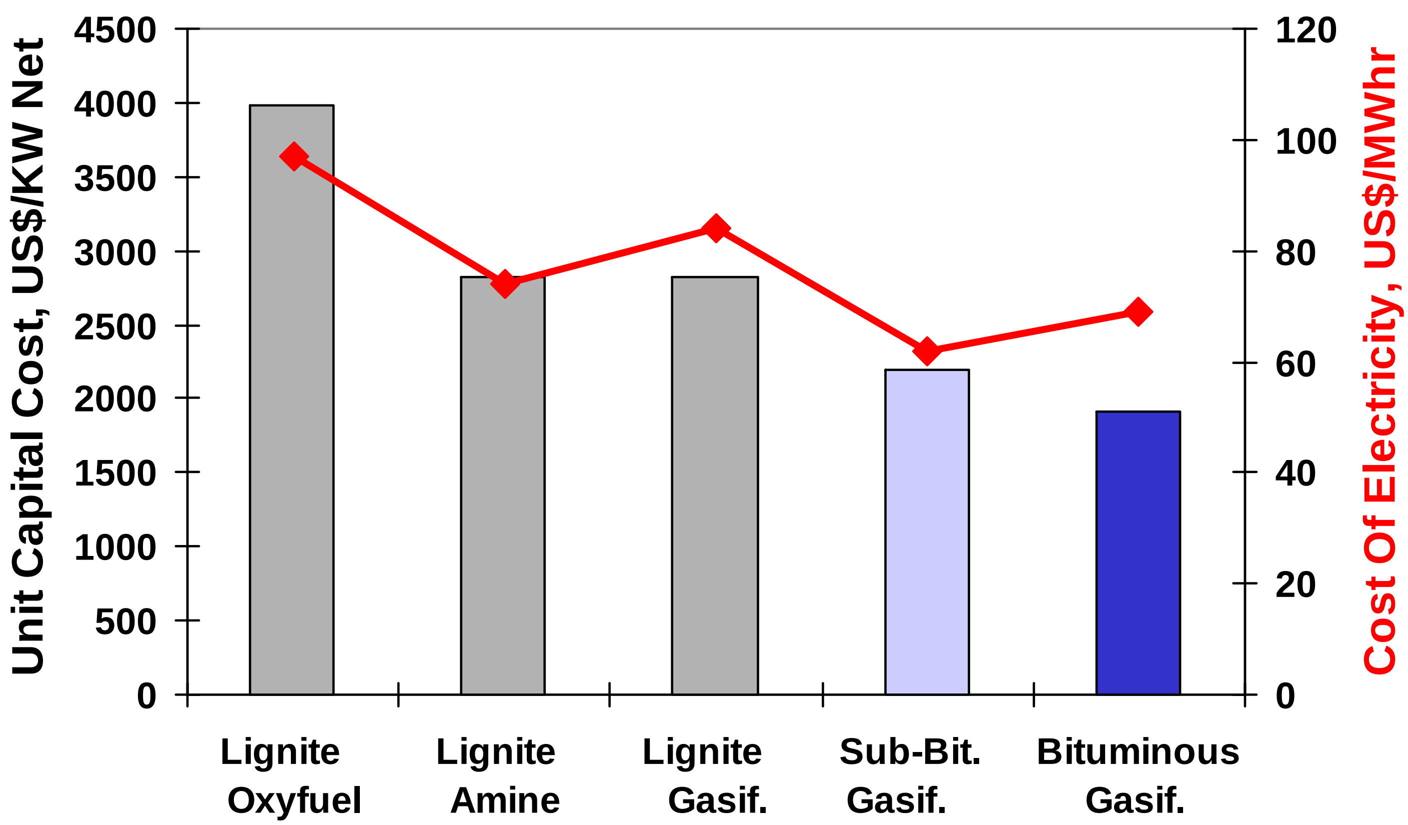
# Retrofit Plants for all Emissions Except $CO_2$ - Capital Costs



# Retrofit Plants for all Emissions Except $CO_2$ - O&M Costs



# Unit Capital Cost & Cost of Electricity Comparisons for 90 % $CO_2$ Capture



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# $CO_2$ Storage and Utilization Options in Western Canada

| Parameter | Enhanced Oil Recovery | Enhanced Coal Bed Methane Recovery | Storage in Depleted Reservoirs | Storage in Deep Saline Aquifers |
|---|---|---|---|---|
| Status | Commercial | Pilot | Commercial | Commercial |
| Capacity Limits | 6-7 projects | None | ➢50 projects | None |
| Breakeven Cost*, $US/t | 24.3 | 6.4 | -2.6 | - |

* Breakeven cost is the maximum that the operator could pay to achieve a zero NPV at a 15% discount rate

# CCPC – Phase I Results

- Texaco Quench evaluated for Pittsburgh # 8 and sub-bituminous coal but Texaco declined to provide data for lignite. Shell selected for lignite.
- Fluor has improved the design of their Econamine (MEA) process for flue gas removal of $CO_2$ reducing the energy penalty from ~1750 to ~1185 Btu of steam/lb of $CO_2$.
- Although the cost of $CO_2$ avoided is lower for IGCC than for amine scrubbing for the bituminous and sub-bituminous coals at grass roots plants the differential is less than with previous studies
- For lignite Shell IGCC with pre combustion $CO_2$ removal was worse than amine scrubbing. All current commercial gasification technologies have poor performance with low rank and high ash coals
- Oxyfuel ($O_2$ with recycle $CO_2$) was evaluated to have a significantly higher COE than amine scrubbing for a grass roots plant.

# CCPC Phase II

- Goal is to fill in technical uncertainties before moving to a firm project.
- Covers the following scope:
  - Gasification technology evaluation to develop better technology for low rank western Canadian coals.
  - Amine scrubbing & $CO_2/O_2$ combustion optimization with advanced supercritical steam cycle.
- Upgrading of the coal prior to burning or gasification, by drying or blending with petroleum coke or other residues, will be evaluated.
- Business case development covering multiple cases:
  - Alberta: coal, bitumen and petcoke gasification
  - Saskatchewan: lignite and petcoke gasification
- Polygeneration of power, hydrogen, steam and $CO_2$ will be evaluated.

# Phase II Status - Gasification

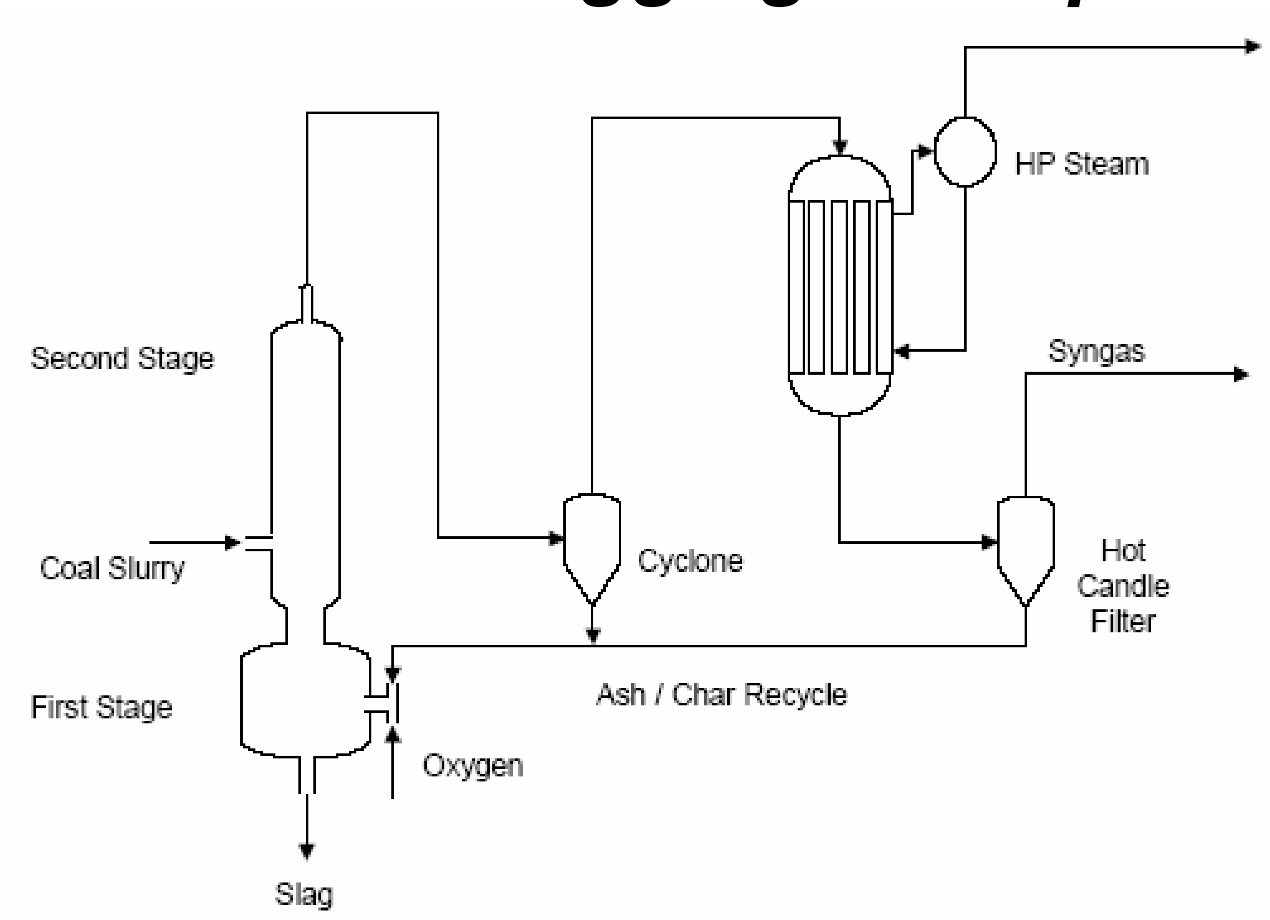
- Gasification study on low rank coal is in progress.
- Review of available gasification processes completed
- Now working with a short list of 3 developers to evaluate benefits of projected gasification process upgrades to performance & costs.
- Focus is on process developments to:
  - increase gasifier pressure
  - simplify gas cooling prior to cleanup
  - improve coal feed systems
- Study will later look at blends of coal & petroleum coke with co-production of power & hydrogen etc.

# Gasification Technologies Considered

- British Gas Lurgi
- *ConocoPhillips **
- EAGLE
- *Future Energy **
- GE Energy
- High Temperature Winkler
- Sasol-Lurgi
- *Shell **
- KBR Transport Gasifier

** Selected for further evaluation*

# ConocoPhillips
## *Entrained Slagging Transport Reactor (ESTR)*



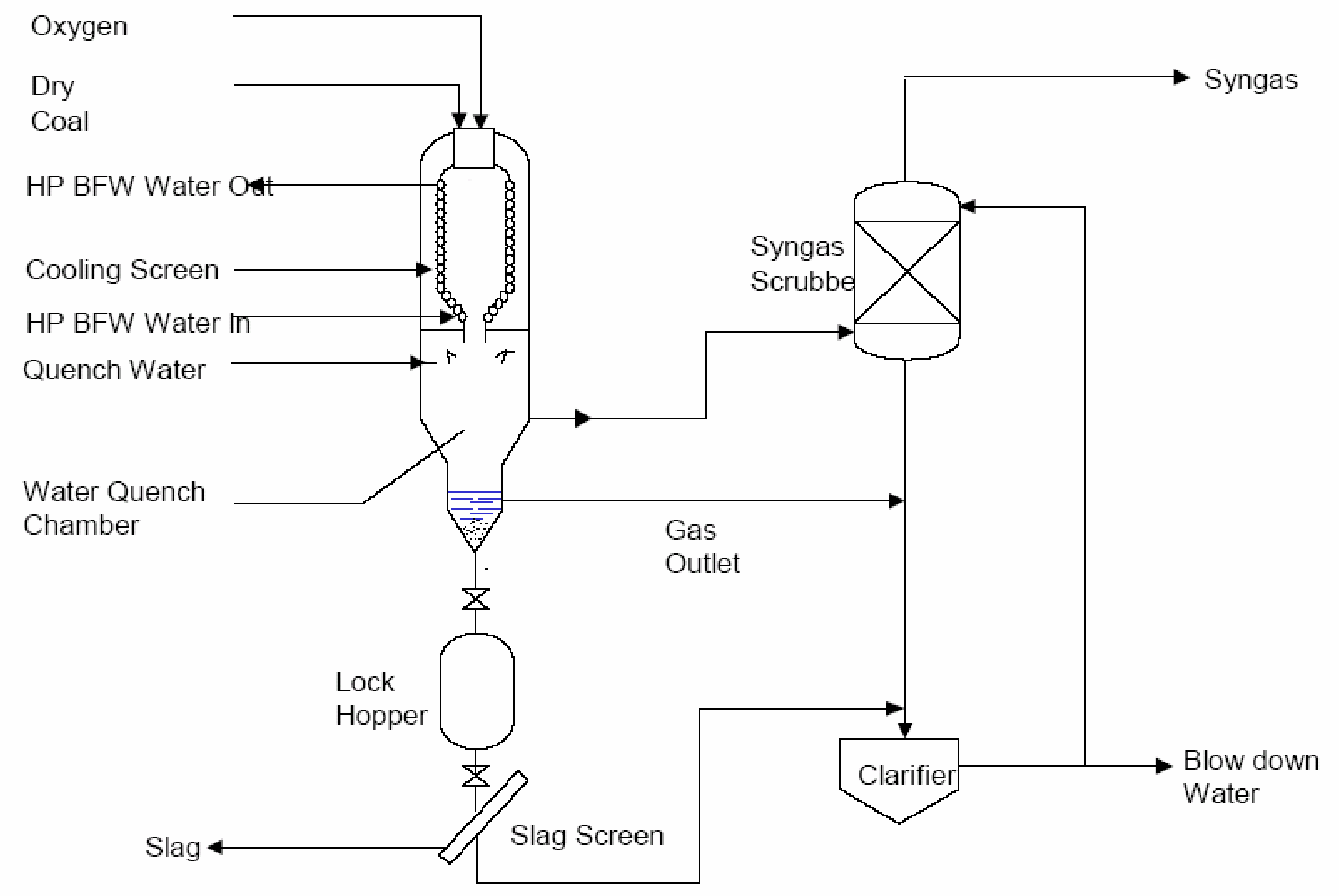

<u>Advantages</u>

- Dry feed to 1$^{st}$ Stage
- High efficiency
- Slagging gasifier
- High pressure operation

<u>Disadvantages</u>

- Refractory lined
- Higher methane content *(could limit $CO_2$ recovery)*
- No water quench

# Future Energy



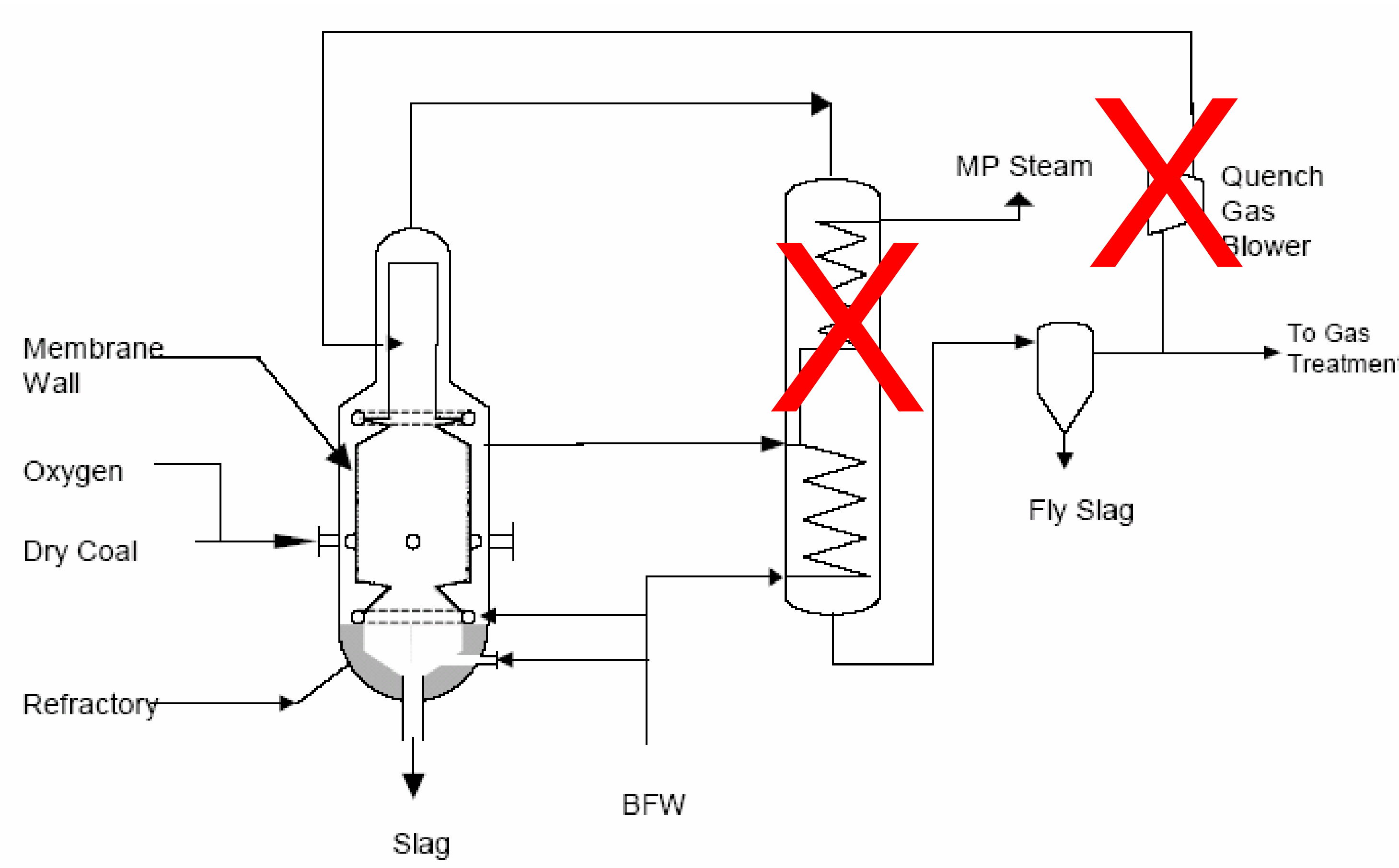

## Advantages

- Dry feed
- Cooling screen
- Water quench
- Slagging gasifier

## Disadvantages

- Lack of operating experience at high pressure

# Shell Coal Gasification Process (SCGP)




Advantages

- Dry feed
- Cooling screen
- High pressure
- Water quench*

Disadvantages

- *No quench option in operation
- Lack of experience at high pressure

# Phase II Status - Advanced Supercritical Steam

- Advanced supercritical steam optimization studies will be done by Mitsui Babcock and Alstom, with support from the UK Government (DTI).
- The MHI advanced amine scrubbing system will be used for amine optimization studies.
- $CO_2/O_2$ combustion optimization will be included, with support from Air Products.
- Studies on thermal integration to improve efficiency will be included in scope (Imperial College).

# Summary of Phase II ASC Case Studies

R0 Base Case Plant – an optimized air-fired ASC PC plant without $CO_2$ capture with appropriate emissions control, assume space is left to retrofit oxyfuel or post-combustion capture

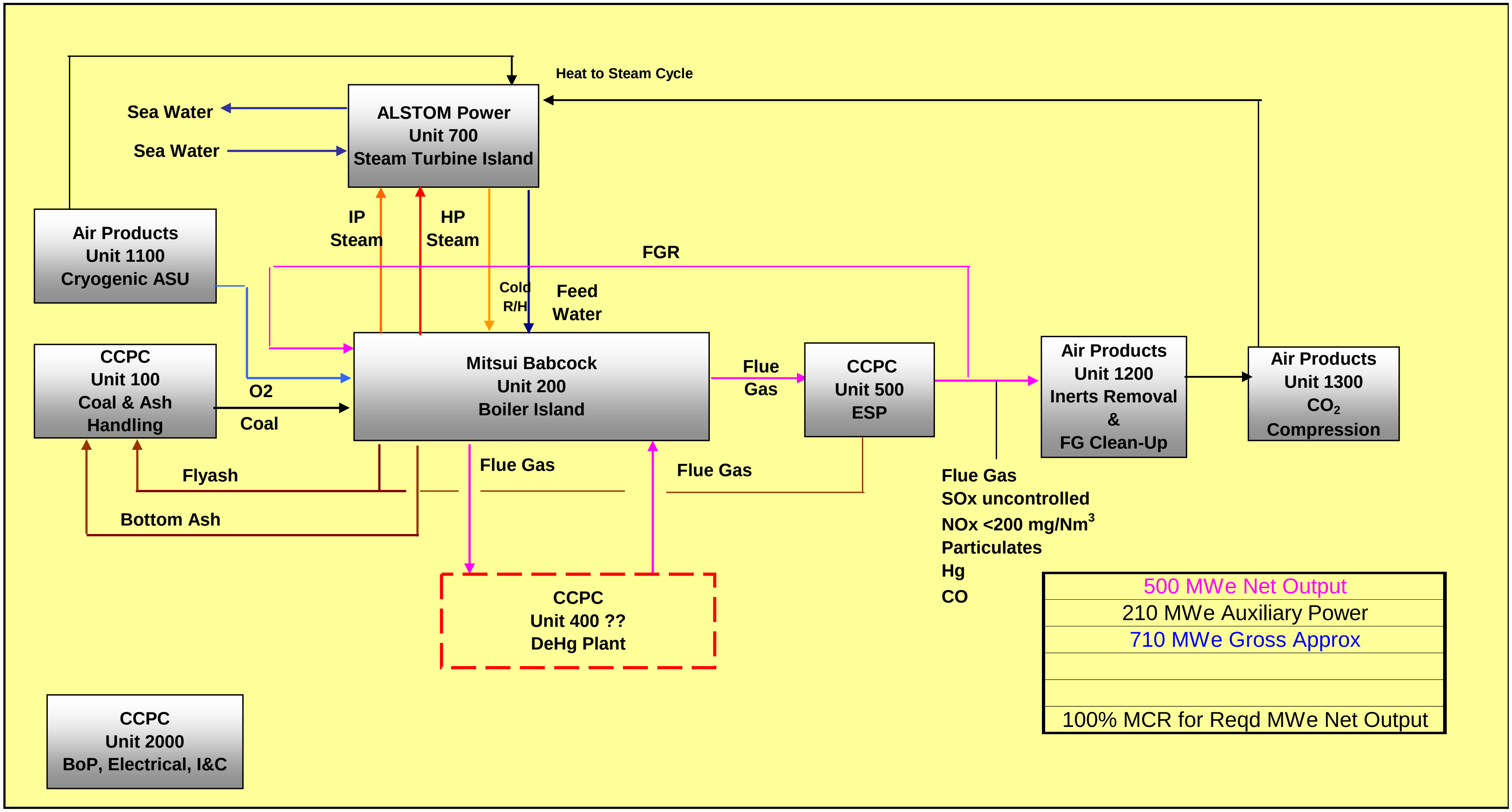
A1 Oxy-Combustion Capture Plant – an optimized oxygen-fired ASC PC boiler with oxyfuel $CO_2$ capture

A2 Oxy-Combustion capture of base case plant – conversion of the base case R0 plant to $CO_2$ capture plus examination of pre-investment options

B1 Post-combustion Capture Plant – an optimized air-fired ASC PC boiler with amine-based post-combustion $CO_2$ capture

B2 Post-combustion capture of base case plant - conversion of the base case R0 plant to amine-based post-combustion $CO_2$ capture plus examination of pre-investment options

# Phase II - Oxy-Combustion $CO_2$ Capture




| |
|---|
| 500 MWe Net Output |
| 210 MWe Auxiliary Power |
| 710 MWe Gross Approx |
| |
| |
| 100% MCR for Reqd MWe Net Output |

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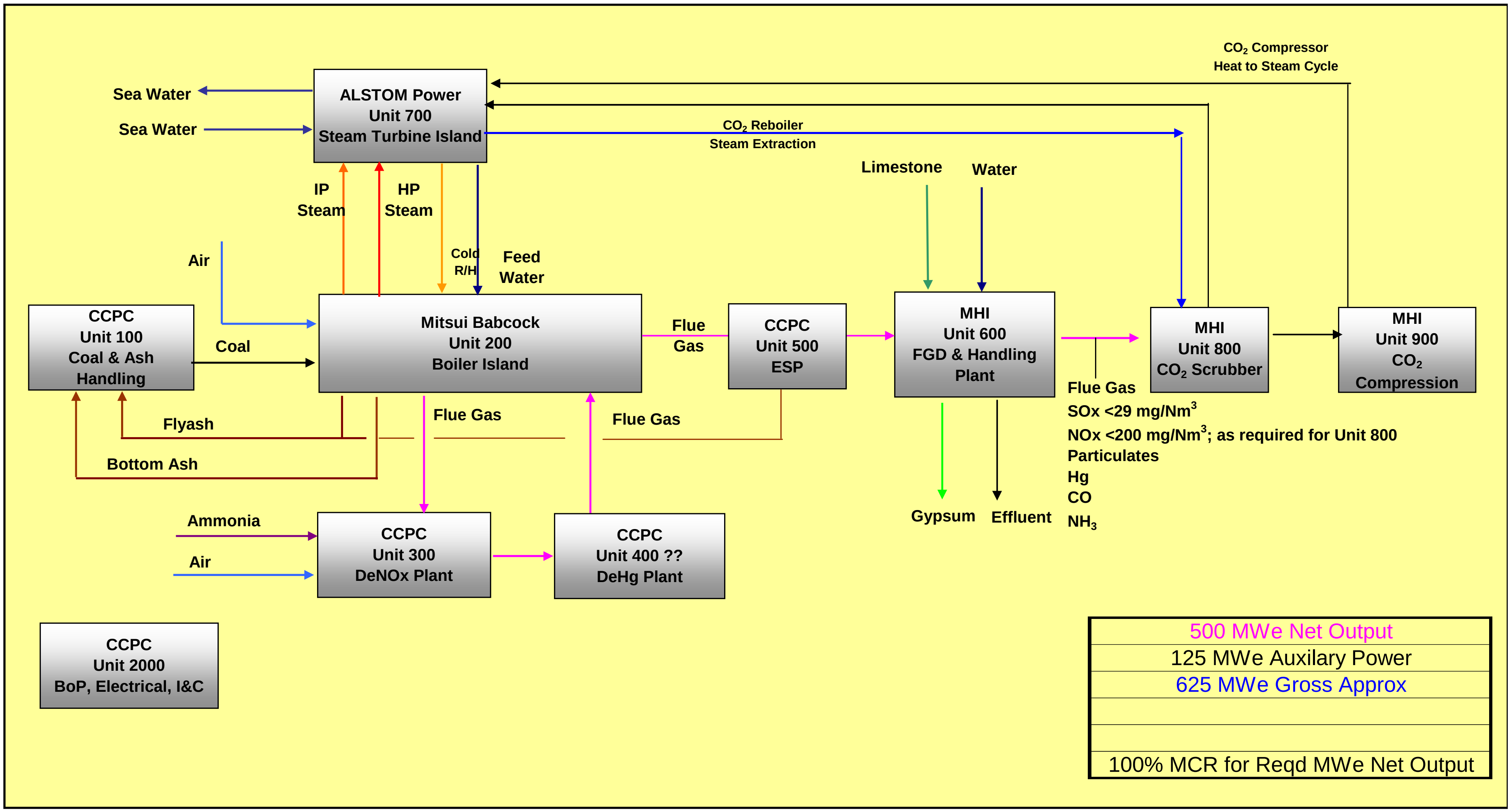
# Phase II - Amine-Based Post Combustion $CO_2$ Capture



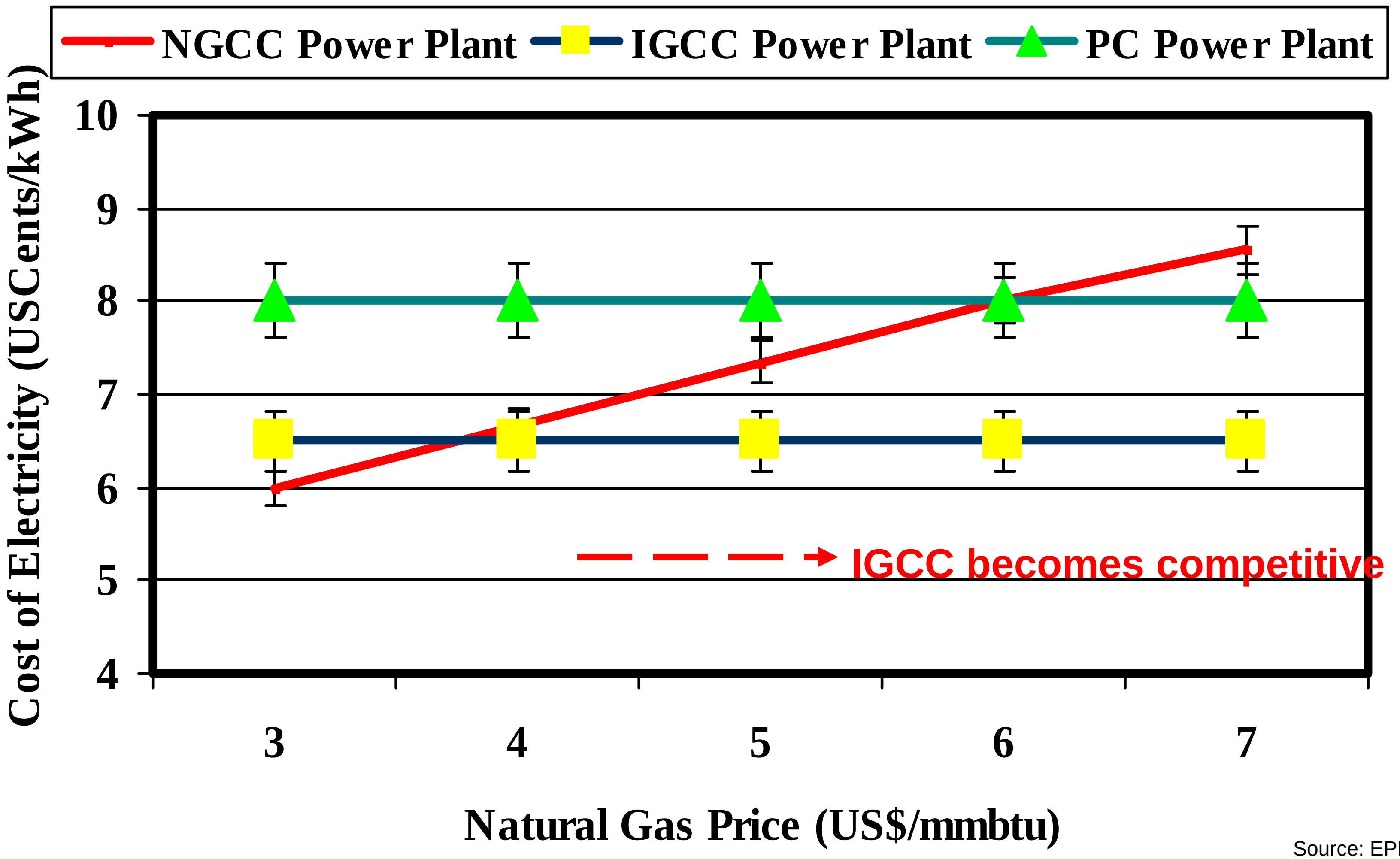
# Expected Phase II Outcomes

- Optimization of the 3 technology options for clean coal with $CO_2$ capture.
- Refine the capital and operating cost estimates, price of power and cost of $CO_2$ removal.
- Develop the business cases to select site and technology for demo project. Possible sites include:
  - Shand in SK and/or Keephills, AB
  - Athabasca Oil Sands, Alberta
  - Refinery applications in Alberta or Saskatchewan that need power, steam, hydrogen
- Will allow planning for the implementation phase to build and operate the demonstration plant to proceed.
- Completion by mid-2006.

# Conclusions

- Production of clean power with 90% $CO_2$ capture and removal of all emissions of concern is technically feasible and can become economically viable at certain locations
- Integrated gasification of low cost fuels (coal, coke) to co-produce power, hydrogen, heat and syngas (polygeneration) offers attractive commercial opportunities in Western Canada based on large markets for:
  - Hydrogen & heat for oil sands operations (replacing high cost natural gas)
  - Synthesis gas for chemical production
  - $CO_2$ for enhanced recovery of conventional oil (EOR) and for extraction of coal bed methane (ECBM). Excess $CO_2$ can be sequestered in deep aquifers
- Gasification costs and reliability depend on feed quality and there is little experience with low rank Western Canadian lignites, sub-bituminous coals and coal-coke mixtures

# Effect of Natural Gas Prices on Electricity
## All plants include 90 % $CO_2$ capture




Source: EPRI, 2003

# Questions?